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Is more area-level crime associated with more sitting and less physical activity? Longitudinal evidence from 37,162 Australians

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Abstract

Does a rise in crime result in increased sitting time and a reduction in physical activity? We used unobserved ("fixed")-effects models to examine associations between change in objectively measured crime (nondomestic violence, malicious damage, breaking and entering, and stealing, theft, and robbery) in Australia and measures of sitting time, walking, and moderate-to-vigorous physical activity (MVPA) in a residentially stable sample of 17,474 men and 19,688 women at baseline (2006–2008) and follow-up (2009–2010). Possible sources of time-varying confounding included age, income, economic status, relationship (couple) status, and physical functioning. In adjusted models, an increase in all crimes of 10 counts per 1,000 residents was associated with an increase in sitting time (hours/day) among men ($\beta = 0.21$, 95% confidence interval (CI): 0.17, 0.25) and women ($\beta = 0.18$, 95% CI: 0.15, 0.22). Counterintuitively, the same increase in crime was also associated with an increase in the weekly number of ≥10-minute walking sessions (men: rate ratio (RR) = 1.01 (95% CI: 1.01, 1.02); women: RR = 1.00 (95% CI: 0.99, 1.01)) and MVPA sessions (men: RR = 1.02 (95% CI: 1.02, 1.03); women: RR = 1.01 (95% CI: 1.00, 1.02)). Similar associations were found for the other area-level crime indicators. While area-level crime prevention may be considered a lever for promoting more active lifestyles, these results suggest that the association is not unequivocal.

Keywords

evidence, australians, longitudinal, less, more, sitting, crime, associated, physical, 37, 162, area-level, activity?

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Original Contribution

Is More Area-Level Crime Associated With More Sitting and Less Physical Activity? Longitudinal Evidence From 37,162 Australians

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Does a rise in crime result in increased sitting time and a reduction in physical activity? We used unobserved ("fixed")-effects models to examine associations between change in objectively measured crime (nondomestic violence, malicious damage, breaking and entering, and stealing, theft, and robbery) in Australia and measures of sitting time, walking, and moderate-to-vigorous physical activity (MVPA) in a residentially stable sample of 17,474 men and 19,688 women at baseline (2006–2008) and follow-up (2009–2010). Possible sources of time-varying confounding included age, income, economic status, relationship (couple) status, and physical functioning. In adjusted models, an increase in all crimes of 10 counts per 1,000 residents was associated with an increase in sitting time (hours/day) among men ($\beta = 0.21$, 95% confidence interval (CI): 0.17, 0.25) and women ($\beta = 0.18$, 95% CI: 0.15, 0.22). Counterintuitively, the same increase in crime was also associated with an increase in the weekly number of ≥10-minute walking sessions (men: rate ratio (RR) = 1.01 (95% CI: 1.01, 1.02); women: RR = 1.00 (95% CI: 0.99, 1.01)) and MVPA sessions (men: RR = 1.02 (95% CI: 1.02, 1.03); women: RR = 1.01 (95% CI: 1.00, 1.02)). Similar associations were found for the other area-level crime indicators. While area-level crime prevention may be considered a lever for promoting more active lifestyles, these results suggest that the association is not unequivocal.

crime; fixed effects; longitudinal studies; neighborhoods; physical activity; residence characteristics; residential stability; sedentary behavior

Abbreviations: MVPA, moderate-to-vigorous physical activity; SEEF, Social, Economic, and Environmental Factors; SLA, Statistical Local Area

In recent years, many scientists have been considering sedentary behavior (e.g., sitting time), independent of physical activity, as an important factor in cardiovascular health (1–4), cardiovascular disease incidence and risk (5–10) (though not always (11–13)), and mortality from all causes and cardiometabolic diseases (14, 15). Attention is turning to what can be done to reduce sedentary behavior (16). The focus has been predominantly upon interventions designed to break up prolonged bouts of sitting, particularly in workplace environments (17–20). Upstream structural constraints, such as the social and built environments in which people live, are also being acknowledged as potentially very powerful influences on sitting time, because of possibly discouraging effects on physical activity (21, 22).

Yet there has been scant investigation of local environmental impacts on sitting time (21), with notable exceptions focusing on "walkability" (23, 24) and "green space" (25). Leafy streets and nearby amenities to walk to are potentially important, but intuition and anecdotal evidence suggest that relatively high area-level crime rates may make physical recreation within an otherwise structurally "walkable" and "green" neighborhood undesirable due to fears over personal safety (26). In other words, the level of crime manifesting within a residential area may play an important role in determining levels of physical activity and sedentary behavior. However, evidence to support that intuition and the co-benefits of investment in crime prevention for health promotion is in short supply (27).

In this study, we hypothesized that longer sitting times, less walking, and fewer instances of participation in moderate-to-vigorous physical activity (MVPA) would result from an increase in area-level crime. A recent debate in this journal on the leveraging of household relocation to understand associations between local changes and walking for transport helpfully raised many of the sensitive issues involved in this important but methodologically challenging area of research (28–30). We extend this debate by refocusing the analysis on residentially stable populations, wherein the environments in which they live change around them. Taking advantage of spatiotemporal variations in rates of multiple types of crime (e.g., nondomestic violence, compared with malicious damage), we aimed to conduct the first longitudinal study to examine whether a rise in the objectively measured crime rate at the area level resulted in an increase in sitting time and decreases in walking and MVPA.

METHODS

Study design

Causal "place effects" on health and lifestyle are notoriously difficult to establish with observational and (especially) cross-sectional data (31). Health-selective migration and unmeasured confounding are key challenges, wherein people with a particular set of health-related circumstances may self-select into (or out of) certain types of places due to shared risk factors (32). This may induce or exaggerate the correlation between 2 variables. To address this challenge, an epidemiologist could examine change in an indicator of sitting time (a proxy for sedentary behavior) between baseline and follow-up in a residentially stable and closed sample (i.e., no addition of new participants through time due to change in life circumstances, such as marriage) with respect to a change in the level of crime that occurs around study participants. Unobserved ("fixed")-effects models eliminate all time-invariant sources of confounding (as long as those sources have a consistent effect on the outcome over time) and, as such, multivariate adjustment is required only for confounding variables that change over time (e.g., age, income, physical health) (33). This combination of sample restriction, dynamic local measures, and econometric modeling helps to address and potentially overcome the aforementioned challenges of causal inference.

Person-level data

Baseline data were extracted from the 45 and Up Study, a study of healthy aging in New South Wales, Australia (34), in 2006–2008. Follow-up data on the same individuals were obtained from the Social, Economic, and Environmental Factors (SEEF) Study, a follow-up study conducted between 2009 and 2010. Approximately 10% of the population aged ≥45 years living in New South Wales (the most populous state in Australia) was included in the sample, having been randomly selected from the Medicare Australia database (the national provider of universal health care in Australia). A self-complete questionnaire was used to gauge a range of health and sociodemographic measures, and a response rate of approximately 18% was achieved (34). The first 100,000 baseline respondents in the 45 and Up Study were invited to complete the SEEF questionnaire, which replicated many of the questions asked at baseline, affording us the option of conducting longitudinal analyses. A total of 28,057 men and 32,347 women completed the SEEF follow-up questionnaire (overall response rate = 60.4%; 3.4 (standard deviation, 0.95) years of follow-up time).

Ethical approval for the 45 and Up Study was granted by the University of New South Wales Human Research Ethics Committee. Ethical approval for the SEEF Study was granted by the University of Sydney Human Research Ethics Committee.

Outcome variables

Sedentary behavior. Overall sitting time was gauged by responses to the question, "About how many hours in each 24-hour day do you usually spend sitting?" Data from this question have been used to examine associations between sitting time and chronic disease (35) and all-cause mortality (36).

Walking and MVPA. Walking and MVPA were assessed at baseline and follow-up using variables derived from the Active Australia Survey (37). The Active Australia Survey assess both frequency and duration of walking for transport and recreation and MVPA (38). Participants were asked, "How many times did you do each of these activities last week?—walking continuously for at least 10 minutes; vigorous physical activity; moderate physical activity (put '0' if you did not do this activity)." A session of walking was defined as consistent walking for at least 10 minutes. Vigorous physical activity was defined as engaging in activities that make a person breathe harder or puff and pant, like jogging, cycling, aerobics, or competitive tennis, but not household chores or gardening. Moderate physical activity was defined as engaging in less strenuous activities, such as gentle swimming, social tennis, vigorous gardening, or working around the household. Discrete counts of moderate and vigorous physical activities were summed to form a single variable. The Active Australia Survey has acceptable test-retest reliability and validity in the adult Australian population and is a useful evaluative tool for detecting physical activity behavior change (39, 40).

Area-level crime rates

Annual crime counts for each Statistical Local Area (SLA) of residence (an Australian census spatial unit) were obtained from the New South Wales Bureau of Crime Statistics and Research. SLAs were the smallest geographic scale on which data were available for analysis in the SEEF Study, with each SLA having approximately 32,000 residents on average in 2006. Data on multiple types of area crime were available for analysis, and our focus was on 4 types that could plausibly act as a deterrent to outdoor physical recreation: 1) nondomestic violence; 2) malicious damage to property; 3) breaking and entering; and 4) stealing, theft, and robbery. Nondomestic violence refers to offenses against the person that take place outside of the household, including (but not limited to) assault, murder, attempted murder, manslaughter, sexual offenses, and harassment. Malicious damage to property refers to the willful destruction of, damage to, or defacement of public or private property, including graffiti. Breaking and entering is the unlawful entry of a structure (e.g., a household or shop premises) with the intent to commit an offense, where the entry is either forced or unforced. Stealing, theft, and robbery includes a range of offenses, including (but not limited to) stealing money or goods from dwellings, motor vehicles, people, or retail stores, with or without a weapon. Crime occurring within a household, such as domestic violence, was not included. An overall indicator of outdoor crime was constructed by aggregating each of the aforementioned types together. Each participant was allocated the annual crime rate of the SLA of residence as an exposure variable corresponding to the years in which he or she completed the baseline and follow-up questionnaires. All crime variables were expressed in units of 10 counts per 1,000 residents, to account for variations in crime counts with local population size.

Potential sources of confounding

The study design implemented meant that only time-varying sources of confounding needed to be resolved via multivariate adjustment. Since there has been little research on the potentially time-varying confounders of sitting time and the likelihood that a person will leave or remain within the same locality, we made a conservative selection based upon research in the areas of physical activity promotion (41), life-course epidemiology (42), and urban demography (43, 44). Time-varying confounders included a participant's age (45–54 years, 55–64 years, 65–74 years, or ≥75 years), relationship status (in a couple or not in a couple), economic status (retired, employed, disabled/suffering from long-term illness, or unemployed), and annual household income (in Australian dollars; ≤\$19,999, \$20,000–\$39,999, \$40,000–\$69,999, or ≥\$70,000). Physical health is also a plausible confounder of both sitting time and residential selection. The Medical Outcomes Study Physical Functioning Scale (45, 46) was used to differentiate between participants in terms of their physical functional capacity. The Medical Outcomes Study Physical Functioning Scale is a 10-item scale that covers a range of activities, from basic actions needed for day-to-day living (e.g., bathing) to more vigorous activities (e.g., climbing stairs). Separate analyses were conducted for men and women, as previous research has indicated that area-level crime might influence health differentially by sex (47). We acknowledge at the outset that while the sex indicator available in our data was time-invariant, this was a methodological limitation, as gender is socially constructed and reflects, to a potentially large extent, clusters of social determinants that can change over time (48).

Study sample

Of 60,404 participants, approximately 5.4% (n = 3,262) were identified to have changed their SLA of residence during the study period. Among the residentially stable participants (i.e., nonmovers), 65.0% (n = 37,162) had data for all 3 outcome variables. The analysis focused henceforth on a complete-case-on-outcome sample, with participants missing covariate data being retained and accounted for using additional categories for each variable. Prevalences and correlates of missing outcome variable data are reported in Web Table 1 (available at http://aje.oxfordjournals.org/). In brief, missing outcome data were more commonly reported among women, older people, participants with annual household incomes of ≤\$19,999, the retired, those not in a couple, and those living in areas with higher overall crime, nondomestic violence, and malicious damage.

Statistical analysis

Data were analyzed in 2015. The characteristics of the study sample and patterns of sitting time were described using cross-tabulations and percentages. The association between a change in area-level crime and sitting time was examined using linear regression. Negative binomial regression was used to perform similar analyses for numbers of walking sessions and MVPA sessions, as the variances of each variable were greater than the mean (i.e., overdispersion). Fixed intercepts for every participant within each type of regression were used to eliminate all between-person effects (i.e., the unobserved effects model) so that only within-person changes through time could be observed. Sex-specific models were implemented in order to detect potentially different associations for men and women separately. Bivariate associations between each outcome and crime exposure variable were examined, followed by adjustment for the time-varying confounders (age, relationship status, annual household income, economic status, and physical functioning). Fixed-effect parameters for the negative binomial regressions were exponentiated to rate ratios. All analyses were conducted in Stata, version 12 (StataCorp LP, College Station, Texas).

RESULTS

A description of the study participants at baseline and follow-up is provided in Table 1. Mean sitting time (hours/day) and numbers of ≥10-minute walking sessions and MVPA sessions per week all decreased over the study period. The count of each crime variable per 1,000 residents also decreased between baseline and follow-up. The income distribution of participants shifted upward, while the percentage of retirees grew. The percentage of participants living as singletons increased marginally, while physical functioning decreased over time.

With the focus of the study on changes in area-level crime, a descriptive analysis of crime counts at the time of each wave was performed (Table 2). Mean crime counts decreased between baseline (wave 1) and follow-up (wave 2) across each indicator. This decrease was particularly apparent for the overall crime variable, but it was less evident for counts of nondomestic violence. We performed further descriptive analysis (Web Table 2) involving exploration of the number of participants subjected to some degree of crime increase, crime reduction, or a consistent rate of crime. The majority of participants lived in areas where the crime rate decreased between wave 1 and wave 2. Compared

Table 1. Characteristics of Participants in a Study of Area-Level Crime, Physical Activity, and Sitting Time, New South Wales, Australia, 2006–2010

Characteristic	Baseline (Wave 1) (2006–2008)			Follow-up (Wave 2) (2009–2010)		
	Mean (SD)	No. of Participants	%	Mean (SD)	No. of Participants	%
Outcome variable						
Sitting time, hours/day	5.65 (3.08)			5.19 (2.95)		
Walking,[a] sessions/week	5.57 (7.76)			5.24 (6.67)		
MVPA,[a] sessions/week	8.06 (13.65)			6.84 (8.61)		
Area-level crime exposure, 10 counts per 1,000 residents						
Total crime	5.70 (2.54)			4.95 (2.15)		
Nondomestic violence	0.20 (0.08)			0.20 (0.08)		
Malicious damage	1.77 (0.70)			1.49 (0.61)		
Breaking and entering	1.12 (0.49)			0.95 (0.46)		
Stealing, theft, and robbery	1.77 (1.01)			1.49 (0.69)		
Age, years	60.6 (10.0)			64.0 (10.0)		
Sex						
Male		17,474	47.0		17,474	47.0
Female		19,688	53.0		19,688	53.0
Annual household income, A$						
≤19,999		5,697	15.3		4,127	11.1
20,000–39,999		7,058	19.0		7,532	20.3
40,000–69,999		7,544	20.3		7,433	20.0
≥70,000		10,589	28.5		13,427	36.1
Missing data		6,274	16.9		4,643	12.5
Economic status						
Retired		15,254	41.1		17,713	47.7
Employed		18,529	49.9		16,359	44.0
Disabled or long-term illness		763	2.1		713	1.9
Unemployed		511	1.4		496	1.3
Missing data		2,105	5.7		1,881	5.1
Relationship status						
In a couple		29,641	79.8		28,905	77.8
Not in a couple		7,466	20.1		8,156	22.0
Missing data		55	0.2		101	0.3
Physical functioning[b]						
Low		9,982	26.9		13,779	37.1
Moderate		10,442	28.1		12,184	32.8
High		12,083	32.5		8,781	23.6
Missing data		4,655	12.5		2,418	6.5

Abbreviations: MVPA, moderate-to-vigorous physical activity; SD, standard deviation.

[a] A session of walking was defined as consistent walking for at least 10 minutes. A session of MVPA was defined as a 10-minute bout or longer.

[b] The Medical Outcomes Study Physical Functioning Scale, a 10-item scale that covers a range of activities from basic day-to-day actions (e.g., bathing) to more vigorous activities (e.g., climbing stairs), was used to differentiate between participants in terms of their physical functional capacity (45, 46).

with other types of crime, a larger percentage of participants were living in areas where the rate of nondomestic violence increased. Fewer than 1.5% of participants lived in areas where the rate of crime remained consistent over the study time period. With more than 98.5% of participants living in areas that experienced some degree of change in area-level crime, the following regression models were models of change-on-change analyses.

Table 2. Area-Level Crime Rates by 45 and Up Study Wave, New South Wales, Australia, 2006–2010

Study Wave	No. of Participants	No. of Crimes per 1,000 People		
		Mean (SD)	Minimum	Maximum
Wave 1 (2006–2008)				
Total crime	37,162	57.0 (25.4)	0	445.1
Nondomestic violence	37,162	6.4 (3.8)	0	69.2
Malicious damage	37,162	17.7 (7.0)	0	111.3
Breaking and entering	37,162	11.2 (4.9)	0	57.9
Stealing, theft, and robbery	37,162	17.7 (10.1)	0	247.5
Wave 2 (2009–2010)				
Total crime	37,162	49.5 (21.5)	0	273.5
Nondomestic violence	37,162	6.1 (3.6)	0	65.2
Malicious damage	37,162	14.9 (6.1)	0	60.1
Breaking and entering	37,162	9.5 (4.6)	0	51.1
Stealing, theft, and robbery	37,162	14.9 (6.9)	0	119.5

Abbreviation: SD, standard deviation.

Table 3 shows the unadjusted and adjusted parameter estimates from unobserved-effects models for all 3 outcome variables. Because unobserved-effects models involve the implementation of a fixed intercept for every participant, only time-varying within-person variation is observable. Thus, the unadjusted coefficient for the regression of total area-level crime on sitting time among men of 0.25 (95% confidence interval: 0.22, 0.29) refers to the association between an increase in the total crime rate of 10 counts per 1,000 population and mean sitting time (hours/day) between baseline and follow-up. Adjustment for time-varying confounders attenuated but did not fully explain the association between change in area-level crime and change in mean sitting time among men ($\beta = 0.21$, 95% confidence interval: 0.17, 0.25). A similar pattern was observed for sitting times among men and women across other crime indicators.

The negative binomial regressions for numbers of walking sessions and MVPA sessions produced more counterintuitive results. Increases in the rate of crime tended to be associated with more walking and MVPA. Reductions in walking and MVPA among women appeared to coincide with increasing rates of nondomestic violence, but these associations did not reach statistical significance ($P < 0.05$).

DISCUSSION

Prolonged sitting as a proxy for sedentary behavior is increasingly recognized as being harmful for cardiovascular health (1–4). For some persons, it is also considered to be independent of physical activity as a risk factor (36). It is likely, though underresearched, that the social and built environments where people live have an impact on how long they spend sitting (21). Crime reported within certain residential areas is likely to promote sedentary lifestyles by making outdoor environments less appealing for social recreation. To our knowledge, ours is the first study to have examined this hypothesis, and we found mixed results. Higher levels of crime were associated with more hours of sitting time but also, unexpectedly, more physical activity. Furthermore, with stronger associations being observed for an increase in the rate of malicious damage, this indicates that the association between area-level crime and sitting time may be strongest when it changes the functionality or aesthetic of the local built environment. Sitting time is therefore likely to be shaped by a combination of structural factors that constitute "livability" (49). One of the key messages from the study is that while interventions designed to decrease or break up long bouts of sitting at the individual level are being funded and have a clear place in public health promotion (17–20), we also need to champion strategies to address upstream structural constraints like area-level crime rates in order to make those interventions sustainable (16).

However, our findings were only partially corroborative since, unexpectedly, a rise in the area-level crime rate was associated with modest increases in walking and MVPA among men and transitions between high-risk groups and lower-risk groups in both sexes. With no other studies having been conducted thus far (to our understanding), direct comparisons with previous work are not possible. There have been studies of the association between area-level crime and physical activity, which could be considered related to sitting time (26, 27), but those findings are largely inconsistent (like ours) and are based upon cross-sectional designs and often use self-reported exposure data (unlike ours). One plausible explanation is that the measures of physical activity available for analysis are generalized and do not specify where a person walks or engages in MVPA, the times at which those activities take place (i.e., weekdays vs. weekends), or the purposes for which they are undertaken (e.g., leisure-time pursuits compared with walking for transport). Had "local neighborhood" and the purpose of the physical activity been specified in the wording of questions posed to study participants, perhaps the observed associations would have pointed in a more intuitive direction.

Table 3. Associations Between Area-Level Crime and Sitting Time, Walking, and Moderate-to-Vigorous Physical Activity, New South Wales, Australia, 2006–2010

Area-Level Crime Indicator	Unadjusted			Adjusted[b]		
	β	RR	95% CI	β	RR	95% CI
Men (n = 17,474)						
Sitting time, hours/day						
Total crime	0.25		0.22, 0.29	0.21		0.17, 0.25
Nondomestic violence	3.00		1.92, 4.07	2.33		1.25, 3.40
Malicious damage	0.94		0.82, 1.06	0.80		0.67, 0.93
Breaking and entering	0.80		0.66, 0.94	0.64		0.50, 0.78
Stealing, theft, and robbery	0.42		0.34, 0.49	0.33		0.26, 0.41
Walking,[a] sessions/week						
Total crime		1.02	1.01, 1.03		1.01	1.01, 1.02
Nondomestic violence		0.96	0.74, 1.25		0.96	0.74, 1.25
Malicious damage		1.07	1.04, 1.10		1.06	1.03, 1.10
Breaking and entering		1.05	1.02, 1.09		1.04	1.01, 1.08
Stealing, theft, and robbery		1.04	1.02, 1.06		1.04	1.02, 1.06
MVPA,[a] sessions/week						
Total crime		1.03	1.02, 1.04		1.02	1.02, 1.03
Nondomestic violence		1.17	0.91, 1.52		1.12	0.87, 1.46
Malicious damage		1.14	1.11, 1.17		1.10	1.07, 1.14
Breaking and entering		1.12	1.09, 1.17		1.09	1.05, 1.13
Stealing, theft, and robbery		1.07	1.05, 1.08		1.06	1.04, 1.07
Women (n = 19,688)						
Sitting time, hours/day						
Total crime	0.22		0.18, 0.25	0.18		0.15, 0.22
Nondomestic violence	1.88		0.97, 2.80	1.44		0.53, 2.35
Malicious damage	0.75		0.65, 0.85	0.66		0.56, 0.77
Breaking and entering	0.55		0.43, 0.67	0.43		0.31, 0.56
Stealing, theft, and robbery	0.41		0.33, 0.49	0.34		0.26, 0.42
Walking, sessions/week						
Total crime		1.01	1.00, 1.01		1.00	0.99, 1.01
Nondomestic violence		0.91	0.72, 1.17		0.90	0.70, 1.15
Malicious damage		1.03	1.00, 1.06		1.02	0.99, 1.05
Breaking and entering		1.03	0.99, 1.06		1.01	0.98, 1.05
Stealing, theft, and robbery		1.01	0.99, 1.03		1.01	0.99, 1.03
MVPA, sessions/week						
Total crime		1.02	1.01, 1.03		1.01	1.00, 1.02
Nondomestic violence		0.91	0.71, 1.15		0.83	0.65, 1.06
Malicious damage		1.10	1.07, 1.14		1.06	1.03, 1.09
Breaking and entering		1.08	1.05, 1.12		1.05	1.01, 1.09
Stealing, theft, and robbery		1.04	1.02, 1.06		1.02	1.00, 1.04

Abbreviations: CI, confidence interval; MVPA, moderate-to-vigorous physical activity; RR, rate ratio.
[a] A session of walking was defined as consistent walking for at least 10 minutes. A session of MVPA was defined as a 10-minute bout or longer.
[b] Adjusted models included age, annual household income, economic status, relationship (couple) status, and physical functioning.

Though misclassification of the outcomes is possible, perhaps because sedentary behavior and physical activity are increasingly being viewed as independent risk factors, it may also be possible that changes in the local environment elicit different behavioral responses. In line with the increasing application of complex systems thinking in public health (50), it is plausible that an increase in crime experienced in one context may have subsequent impacts not only on behavior contemporaneously but also on other aspects of life. Place-related substitution effects may actually result in positive co-benefits for individuals. For example, if the result of rising crime is that a person no longer feels safe jogging alone in his/her neighborhood, rather than giving up on physical activity the person may instead elect to join a running club or engage in another group-based activity, therefore benefiting from potential increases in social capital (51) in addition to maintaining (or even enhancing) an active lifestyle in a perceptibly safer environment. Future epidemiologic research contrasting environmental impacts not only on changes in sedentary behavior and physical activity but also on adaptation strategies that some people may use to retain their lifestyles is warranted.

It is important to recognize that official area crime statistics such as those we used have limitations, including potentially geographically uneven underreporting of minor offenses (e.g., graffiti) and also of more serious crimes due to embarrassment or fear of potential retaliation (52). Moreover, the geographic identifier used for participants in the Australian epidemiologic data—"SLA"—is (ironically, given the name attributed) likely to be an inadequate descriptor of local area circumstances. Our previous research indicated that levels of crime experienced on finer geographic scales may elicit more pronounced changes in behavior than crime manifesting further afield (53). As such, it may be that the coarser geographic specification of the crime exposure variables used here may be a driver of these counterintuitive results. Neither the perceived risk of crime nor the fear of crime—probable mediators of the environmental impacts of crime on behavior—necessarily correlates strongly with actual crime reported within a locality (54). It is plausible that these subjective factors are influenced more by visual stimuli, such as instances of malicious damage, which may go some way toward explaining the stronger associations with sitting time observed in our study (47). Our previous research indicated that increasing area-level crime rates are associated with an increased risk of psychological distress (55), which is strongly associated with perceptions of safety (56, 57). Causal mediation analyses (58–60) with objective and subjective crime measures could prove a useful next step should appropriate data become available.

An additional limitation of our findings is that while the SEEF Study (wave 2 in this analysis) had a response rate of 64%, the 45 and Up Study (wave 1 in this analysis) on which it was based had a response rate of just 18%. Some research has suggested that results from the 45 and Up Study are comparable with those of an adult population health survey conducted in the same state of Australia (61), though there is naturally still some concern over the representativeness of a sample based upon such a small response rate. That being said, a recent high-level debate on whether representativeness is something that should be of utmost concern in epidemiologic studies suggested that this may not be a major limitation (62–67).

While no panacea, the longitudinal design employed in our study afforded us a clear enhancement of existing knowledge through leveraging of a natural experiment that could not have been replicated as a randomized trial, by focusing on participants who did not relocate while incorporating dynamic local measures of exposure. This type of design is rare in the study of "place effects," as large sources of geocoded prospective data are uncommon and changes in local environments are often isolated and restricted to a small number of places. Focusing on a residentially stable sample has the additional benefit that it restricts bias due to neighborhood selection, which can potentially influence studies that take advantage of natural experiments involving household relocation, as was recently debated within this journal (28–30).

In conclusion, our findings suggest that an increase in the area-level crime rate may well have potentially harmful consequences for cardiovascular health risk by increasing sitting time. It is increasingly well acknowledged that the protection of cardiovascular health requires concerted preventive efforts with regard to upstream determinants (22, 49). In this regard, it would appear that investments in crime prevention—and in the prevention of crime that directly influences the built environment in particular—are potentially also investments in addressing sedentary behavior and its associated health implications. Because no "mirror image" reflection of the sitting time findings for walking and MVPA was observed, however, we still have some way to go before we have a full understanding of the impact of area-level crime on active living.

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